NeurOnline: A software to perform online analysis and control of electrophysiological recordings

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Project Summary
It is now standard to record the activity from large numbers of neurons simultaneously, both in behaving animals using acute or chronically implanted electrode arrays, and in brain slices or tissue cultures using substrate-integrated multi-electrode arrays. To enable control and intervention in an ongoing experiment, it is important to monitor certain critical parameters of the recorded activity in real-time. NeurOnline is a software that enables the researcher to perform online analysis of their electrophysiological recordings and to suitably interact with their experimental setups based on these analysis results. Specifically, our software supports optimizing the yield of experiments by providing new algorithms for online analysis that give comprehensive feedback about the status of the experiment in real-time. In addition, we hope to stimulate the development of novel experiments based e.g. on the possibility of fast adaptation of applied stimuli depending on the behavior of the system studied. The software is made publicly available under GPL.

Technical details
The software architecture chosen for this project consists in Python scripts that call C++ extensions provided by SIP. The C++ language allows high-performance computations that are crucial for time-critical "online" analyses and an easy use of multiple threads. The Python scripting language, on the other hand, enables experts and semi-skilled programmers at the same time to easily use and extend the envisaged software toolbox. The QT library is used to implement a signal/slot mechanism. A graphical user interface permits to control the analysis and displays the results of all computations performed on the recorded data.

Based on a set of open source drivers ("comedi"), NeurOnline can currently interact with 400 different data acquisition boards (e.g. National Instruments) that are commonly employed in electrophysiological setups. A TCP/IP client has been implemented to allow the communication with high-density multi-electrode arrays (HD-MEAs) currently developed at ETH Zurich/Basel. These devices currently allow sampling from 128 channels (selected from a set of 11,000) at a sampling frequency of 20 kHz per channel. Acquisition from Multichannel Systems multi-electrode arrays is also supported.

A butterworth IIR online filter has been developed to select the appropriate frequency bands of the recorded signals. Online spike sorting is performed on the detected spike waveforms by applying a dynamic template matching algorithm. The Python interface allows NeurOnline to send signals that depend on the result of online signal analysis to other processes, e.g. to update in real-time the visual stimulus displayed by some dedicated software (e.g. "VisionEgg").

NeurOnline is currently used in two laboratories: At the Biomicrotechnology laboratory (IMTEK, University of Freiburg) the dynamics of dissociated cell cultures grown on HD-MEAs are studied. Those arrays have 11,000 recording sites, 128 of which can be recorded at the same time. NeurOnline is currently used to record the data from subsets of electrodes, to detect the spikes in the recorded signals and to organize the scan of the full set of electrodes depending on the recorded activity. At the Neurobiology and Biophysics laboratory (Faculty of Biology, University of Freiburg), extra- and intra-cellular recordings in the neocortex of anesthetized rats are performed. Visual stimuli that preferentially activate neurons in the thalamus (LGN) and in the primary visual cortex (V1) are selected by a method known as adaptive sampling. NeurOnline used in this laboratory for multi-channel signal recording, spike detection, spike sorting and visual stimulus updating.

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